entiate in sewage waters; but it is probably killed in those waters, by exposure to sunlight, before this power is entirely lost. The members of the colon bacillus group which have been obtained by the writer from contaminated waters have rarely possessed the fermenting power which is found in cultures obtained from the normal intestines of man; they may be in a 'transitional' state.

The greater loss of fermenting power with saccharose than with other sugars, may be attributed to the nature of the sugar, which is not directly fermentable, but must first be inverted by a ferment, dextrose and levulose being formed, in which the process of fermentation is easily carried on. The duration of the fermenting process of the colon bacillus with saccharose is much longer than with other sugars.

The diminution in fermenting power noted in cultures obtained from organs undergoing inflammation will be further studied in connection with the influence of proteid materials on the colon bacillus.

My thanks are due to Dr. J. S. Billings and Dr. A. C. Abbott for direction in this work, and assistance in obtaining cultures; and also to Dr. Henry W. Cattell, who has furnished me with much valuable material.

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SUPERHEATED STEAM IN STEAM ENGINES.

THE writer has been, for many years, much interested in the now century-old problem of the application of superheated steam to use in the steam-engine with a view to the extinction of those internal thermal wastes which have, from the days of Watt, been recognized more or less clearly as the most formidable obstacles in the way of improvement of the efficiency of the steam-engine, as in fact, of all known heat-motors. The material which has been meantime collecting was recently collated and abstracted, and finally published in a paper read before the American Society of Mechanical Engineers at its St. Louis meeting of 1896.* The subject has more of scientific than practical interest at the moment; but it is not impossible that the resuscitation of this once accepted and now comparatively little-used process may yet prove to be the means, and the only practicable means, of continuing indefinitely the improvement of the steam-engine begun by Watt a century ago. The alternative seems, at the present time, to be the discovery of some commercially practicable method of

* Superheated steam; facts, data and principles relating to the problem. Trans. A. S. M. E., 1896, Vol. XVII.

producing a non-conducting working cylinder and thus of approximating the real to the ideal thermodynamic machine, a method discussed by the writer at some length in a recent issue of the Transactions of the U. S. Naval Institute.

The following is a summary of the conclusions presented before the American Society of Mechanical Engineers:

* * * *

Opinion seems substantially unanimous, and all testimony confirms the conclusion that superheat may effect large net economies. Collating the results of about fifty authentic and well-conducted experiments, it is found that the gain in fuel, by the introduction of superheating, ranges from ten to fifty per cent. of the fuel used with wet steam; that about 100 degrees superheat, on the Fahrenheit scale, gives usually complete extinction of initial condensation; that even fifteen or twenty degrees will make an important gain in reduction of internal wastes; that every application of this system, discreetly effected, returns several times—actually from two to ten times—its cost in heat expended; that the largest returns are secured by the smallest quantities of superheating; and that the indications are, so far as we can to-day judge from earlier and contemporary practice, good engineering in this direction pays, and pays well; the limit being found at that point, continually becoming more remote and at a higher and higher temperature, at which excess of temperature begins to cause rapid destruction of the superheating apparatus, and consequent expense and danger in such degree as to become a large and more than counterbalancing element. The average of fifty-two cases observed by the writer gives a gain of twenty-six per cent. with a superheat of 105 degrees Fahr. The average gain with compound engines examined is twenty per cent. with a lower but uncertain amount of superheating, in a majority of the cases reported the superheat not having been measured. In cases averaging about fifty degrees superheat, the gain was twenty per cent., and this is probably not far from the average for all.

* * * *

Thus, one thermal unit, one pound of steam or of fuel, or one dollar, expended in reduction of this internal waste, returns three; and a profit of three hundred per cent. pays, in turn, the excess of cost of maintenance of superheating apparatus and incidental costs and repairs at engine and at boiler.

Where the gain by use of superheating is less, the proportion of profit to expenditure is, as a rule, greater, since the effect of the first few degrees of elevation of temperature and of superheat is by far the most effective in reduction of initial condensation.

The conclusions of the writer are the following:

(1) Superheated steam, as hitherto employed in the steam-engine, has absolutely no purely thermodynamic value. It neither raises the upper limit of temperature nor depresses the lower; it gives no increased range of temperature of the cycle; the value of the maximum measure of ideal efficiency, $(T_1 - T_2)/T_1$, is in no manner altered by its introduction into the system.

On the other hand, it is evident, from a study of the physics and thermodynamics of the case, that, could any way be found of practically working superheated steam, safely and with economy in its production, it would permit a thermodynamic gain only limited by the extent to which the range $T_1 - T_2$ could be thus expanded.

(2) Superheating has for its sole purpose and result, in the steam-engine to-day, the extinction or reduction of the internal thermal wastes of the engine, consequent upon the phenomenon known as initial or 'cylinder condensation.' Here it is extraordinarily effective, and a small quantity of

heat expended in superheating the entering steam effects a comparatively large reduction in the expenditure of steam in the engine; each thermal unit thus employed saving several thermal units otherwise wasted. The process is one, mainly, at least, of prevention rather than of cure of that fault; and prevention is, as usual, here found to be vastly more effective than attempted cure.

(3) Superheating is superior to any other known means of reduction of internal waste. Jacketing ordinarily suppresses but a fraction of that waste, and the multiple-cylinder engine has also its limitations; while superheating may not only extinguish it, but may also check wastes due the resistance to flow of the denser, wet steam through steam and exhaust ports, and may sensibly improve the vacuum attainable in the condenser, with corresponding reduction of back pressure, of the quantity of condensing water demanded, and of the load on the air pump.

Superheating even a few degrees improves considerably the performance of the engine, and, in the average case, superheating one hundred degrees Fahrenheit will entirely extinguish that waste.

(4) The hitherto unconquered obstructions to the use of superheated steam in the engine have been those resulting from destruction of packing and decomposition of lubricants, with consequent friction and 'cutting' of the rubbing surfaces. The introduction of metallic packings and of high-test lubricants has now enormously reduced the difficulties of application of superheating. No trouble need now be found at the engine with sufficient superheating, under usual conditions of operation, to annihilate cylinder condensation. It seems not at all improbable that even this limit may be ere long safely, and perhaps even largely, overpassed, with resulting improvement of thermodynamic efficiency.

(5) The obstruction at the boiler has been, and still remains, difficulty of construction of a superheater, or of a superheating system, which will be at once effective, safe and durable.

The comparatively low temperatures at which modern boilers discharge their gases into the uptake, while reducing these difficulties largely, introduces the complementary one of increased necessary area of superheating surface, and consequent volume, weight and cost of the superheaters. The real difficulty is to-day found at this point, and the production of a superheater which will safely withstand the effects of high temperature of flue gases, will effectively transfer heat from gas to steam, and will have a satisfactorily long life, still challenges the engineer as one of his most serious, yet attractive and important problems.

(6) The more wasteful the engine, the larger the promise of gain by superheating, and small engines will profit by it more than large, slow engines more than fast, and simple engines more than the multiple-cylinder systems, which latter require such auxiliaries less as their cascade action is the greater and its steps more numerous.

(7) The larger the waste to be checked in the engine, the farther should the superheating be carried. That degree which would serve every purpose in the simple, slow, small mill engine would be entirely too high for safe use, and quite inexpedient, in the high-speed compound of large size, while that which would be ample for the latter would be entirely insufficient for the former.

(8) The extent of superheating should be adjustable—not only to the particular size and type of engine in view, but also in the same engine—to the extent to which expansion is carried.

A perfectly satisfactory system of superheating should be adjustable in this respect with the load on the engine, and still free

from danger of burning out at light loads, while giving suitable action at heavy loads. In the one case it must supply a small amount of highly superheated steam to the engine, in the other a larger quantity with less superheat.

This presents the engineer with a problem not yet really attacked.

(9) The average simple engine may be said, under such conditions as we are most familiar with, to demand a quantity of fuel annually, about equal in value to its own first cost. In such cases it is obvious that under these conditions, and with the above return of five dollars in saving to each dollar paid to thus reduce waste, it will pay to annually expend the full equivalent of the interest on the price of the engine in maintaining a good superheating system. When, however, as has usually hitherto happened, this account includes such large interest and wear-and-tear accounts as cause the total annual expense to exceed this financial limit, the engineer will wisely decline to thus invest capital.

Studying the results of experiments to date determining the magnitude of the internal wastes which superheating is expected to reduce, we shall find that the following may be taken as, roughly, the measure of those wastes, the relative quantities of heat gained by their complete extinction and the extent of the necessary superheat:

GAIN BY SUPERHEATING.

ENGINE.	Steam pressure, pounds per square inch.	Percentage steam condensed, without superheating.	Relative gain by superheating.	Degrees Fahr. superheat.
Simple.........	50 to 100	50 to 30	5 to 1	100
Compound.....	75 to 125	30 to 20	3 to 1	75
Triple..........	125 to 180	20 to 10	2 to 1	50

(10) Given a safe and durable and efficient superheater, and the engineer will have the power to adjust his temperatures and pressures of working fluid to any limit that may be sent by the character of his materials in boiler and engine, and to secure the best adjustment of the thermal to the dynamic limit.

In other words, he may produce a working fluid having at once the high temperature and wide range of adiabatic expansion requisite for maximum thermodynamic efficiency, and the high initial and mean effective pressures needed to insure maximum dynamic efficiency or efficiency of the mechanism of the engine; the two combined thus giving the maximum total efficiency obtainable by any means whatever. The high thermodynamic efficiency of the gas engine and the peculiarly high 'efficiency of machine' characteristic of the steam-engine would be both secured, and the steam-engine once more placed beyond rivalry among all the heat-engines.

(11) This is, to-day, the greatest of all the problems presented the designing and constructing engineer, with the possible exception of that of finding a system of effectually rendering the interior of the working cylinder non-conducting, in such manner as to prevent entirely the occurrence of initial condensation, thus conforming the 'ideal case' to the real, and making the steam engine a purely thermodynamic machine.*

The above are the main points of the paper, so far as especially interesting from a scientific point of view. It includes, in a monograph of some seventy pages, a collection of facts, data, and results of experience and of direct experimental tests of engines and boilers, as well as opinions of distinguished authorities and practitioners, which, while valuable as a basis for its deductions and final conclusions, would be out of place here. But even these omitted sixty pages constitute but a fraction of all

* 'The Final Improvement of the Steam Engine,' R. H. Thurston. *Transactions United States Naval Institute*, 1891; *Sibley Journal of Engineering*, 1892.

the material accummulated, having value to the expert engineer and corroboratory of those conclusions. In the opinion of the writer, the latter may be accepted as thoroughly well-established.

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ON CERTAIN PHYSICAL DIFFICULTIES IN THE CONSTRUCTION OF LARGE GUNS.

The substitution of forged steel for cast iron in gun construction has resulted in the universal adoption of the built-up gun. About the year 1855 the Englishman, Blakely, and the American, Treadwell, independently discovered and demonstrated the value of the principle of initial tension as a means of increasing the strength and economizing the material of a gun. What this means can be briefly shown.

Assume a tube of perfectly annealed metal with given tenacity and elasticity. If a powerful stress be applied, there is no reason why one part should be more capable of resisting it than another. Let the tube be closed at one end, and let the stress originate from within near this end, as in the explosion of a charge of gunpowder. Under this condition it was shown by Treadwell that if we assume the tube to be made up of a large number of uniform, cylindrical, concentric layers of metal, then the resistance of each layer to the exploding force will vary inversely as the square of the diameter. The stress in its effect upon the metal decreases at a rate quite similar to that of the radiation of heat or light. If the wall of the tube be under no initial stress its inner surface may be stretched even to its elastic limit, while the stretching of the outer surface is comparatively slight. The metal's property of elastic resistance is hence not utilized to the best advantage in the outer layer, while in the inner layer it may be utilized to an extent inconsistent with safety.

Treadwell therefore proposed a plan of gun construction which has since been universally adopted. The modern gun consists of a steel tube which is reenforced by one or more concentric hoops or tubes, the number and position of these being adjusted to the variation of pressure from within as the hot exploding gas finds vent at the muzzle. The ordinates of the pressure curve are greatest at the origin, this being taken as the middle of the seat of the powder charge in the chamber. They decrease rapidly with approach to the muzzle. The reenforcement of the tube should therefore be greatest around the breech. A tubular jacket is shrunk on around the main tube, covering the breech and often as much as two-thirds of the entire length. Around the jacket is a series of compressing hoops, and around this there may be a second or outer series of supplementary hoops. Originally the interior diameter of the jacket is a little less than the exterior diameter of the tube. By heating the jacket sufficiently it is made to expand until large enough to be slipped into place over the cold tube. This becomes enormously compressed by the subsequent cooling of the jacket. In like manner the first hoop is too small to be slipped over the cold jacket until sufficiently heated for this purpose. The same remark applies to the relation between the second and first hoops. The final result is that the diameters of the tube, both external and internal, are permanently decreased by the compression of the jacket, while those of the hoops are permanently increased. Their contractile force is not enough to compress the jacket into smaller space, for this itself is pushed outward by the powerful reacting force of the compressed tube within. The hoops, therefore, serve to reenforce the jacket by their own tendency to contract. Having been put on in an expanded condition and prevented from recovering their normal dimensions,